forest management note

Note No. 38 Northern Forestry Centre Edmonton, Alberta

GROWTH OF 25-YEAR-OLD LODGEPOLE PINE AFTER JUVENILE SPACING IN WESTERN ALBERTA

Naturally regenerated stands of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) are often overly dense following wildfires or logging and scarification. Excessive stand density stagnates tree and stand growth. Juvenile spacing and precommercial thinning are thus prescribed to rectify this problem (Alexander 1965; Barrett 1961; Cole 1975; Dahms 1967; Daniel and Barnes 1959; Johnstone 1981a, b, 1982).

A study was initiated in 1967 to monitor lodgepole pine stand development at various spacings to derive spacing and thinning guidelines. Ten-year results of the study have been reported by Johnstone (1982). This Note presents results to 15 years after treatment and gives some tentative guidelines for managing lodgepole pine in western Alberta.

METHODS

The study area is located in the Bow-Crow Forest near the junction of the Forestry Trunk Road and Tepee Pole Creek (51°53′, 115°03′). The stand originated in 1941 following a wildfire. Forests in this area are within the Upper Foothills Section (B.19c) of the Boreal Forest Region (Rowe 1972). Lodgepole pine is the predominant species, and there is an admixture of black spruce (*Picea mariana* (Mill.) B.S.P.).

Stand selection, site description, study design, and establishment of this study were described by Johnstone (1982). The study was established on three different site types. These were as follows: 1) good site on a level, well-drained Brunisolic Gray Luvisol developed on Cordilleran till, with a fluvio-aeolian veneer; 2) medium site on a south slope with a well-drained Brunisolic Gray Luvisol on Cordilleran till over sandstone; and 3) poor site on a north slope with a well-drained Eluviated Eutric Brunisol developed on a sandy loam-textured Cordilleran till.

Plots varying in size and comprising trees in a 10 × 10 matrix were established. Five different spacings were used on each plot (Table 1). Each of these grid intervals was used twice on each site.

After plot establishment, trees were tagged and diameter at breast height outside bark (dbhob) was measured in the fall of 1967 and was remeasured every five years, i.e., in 1972, 1977, and 1982. Height, crown length, dbhob, and crown width were recorded for each tree.

Stand height was calculated as the average height of all trees; stand diameter was the quadratic mean diameter. The total volume of each tree was calculated from volume equations developed by Kirby[1] and summed up for each plot. For stand diameter, height, and total volume growth, only data from the inner 64 trees in each plot were used, to eliminate the possible confounding of edge effect. Analysis of covariance was used to assess the effect of spacing on stand diameter and height at each measurement period using initial (1967) values as a covariant.

[1] Kirby, C.L. 1973. Unpublished file report on tree volume equations and volume basal-area ratios for white spruce and lodgepole pine in Alberta. Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta.

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Table 1. Grid interval, spacing, and size of treatment plots

Stocking level	Grid interval (m)	Spacing		Plot size	
		Stems/ha	Stems/acre	ha	acre
1	4.5	494	200	0.200	0.500
2	3.2	988	400	0.101	0.250
3	2.3	1 977	800	0.051	0.125
4	1.6	3 954	1 600	0.025	0.063
5	1.1	7 907	3 200	0.013	0.031

For mortality analysis, all trees within the matrix were used. Percentage mortality (number of stems, basal area, and volume) was based on a 5-year measurement period. The percentages were transformed before analysis to conform to the basic assumptions of the analysis of variance.

RESULTS

Stand diameter, height, total stand volume, and mortality were variously affected by spacing.

Stand Diameter

On all three sites, stand diameter consistently increased as spacing increased (Fig. 1). Differential responses of diameter growth to various spacings appeared 5 years after spacing. The differences in stand diameters between the widest (4.5-m) and the closest (1.1-m) spacings increased with time.

The effect of spacing on diameter growth was also site dependent ($P \leq 0.05$). On the poor site, stand diameters in spacings of 4.5 and 3.2 m were the same in all three measurement periods (Fig. 1). Apparently space has not become limiting for tree growth at these two spacings. On the medium site, differences in diameter growth between these two spacings began to show at 40 years, while on the good site, differences in diameter growth between 4.5-m and 3.2-m grid intervals were observed throughout the three periods (Fig. 1).

Height

Spacing had a significant effect on mean height growth, but site ($P \leq 0.001$) had a more pronounced influence on height than did spacing ($P \leq 0.01$). Stand height increased with stand density on the good site but was unaffected by spacings on the poor and medium sites 5 years after treatment (Fig. 2). Ten years following spacing, 4.5-m spacing had the shortest heights on all sites. Tree height on all three sites declined when density increased from 1.6- to 1.1-m intervals and reached significance ($P \leq 0.05$) in the third period.

Total Stand Volume

As expected, the 4.5-m spacing had the lowest total volumes per hectare on all sites, and close spacings (1.8-or 1.1-m) had the largest. Differences in total volume between the wide and close spacings increased with time (Fig. 3) especially on better sites.

Mortality

In terms of the number of dead trees 15 years after treatment, 1.1-m spacing had the highest mortality (8.15%), and 2.3-m had the lowest (3.12%) (Table 2). Spacing of 4.5-m had considerably higher mortality (6.77%) than the intermediate spacings. Fifteen years after treatment the closest spacing leaves 6 100 stems/ha compared to only 400 stems/ha in the 4.5-m spacing; these 400 lodgepole pine per hectare are insufficient to fully utilize the site in the boreal forest.

In terms of basal area percentage loss, the 4.5-m spacing had the highest loss and the 2.3-m spacing had the lowest. Percentage mortality in the three intermediate spacings was similar. Basal area loss at 4.5-m spacing was significantly higher than in the intermediate spacings. The pattern remained the same in volume losses (Table 2).

Percentage mortality varied over the three measurement periods ($P \leq 0.01$) (Fig. 4, Table 2). Overall, the trends over three periods were strongly linear, but two distinct patterns in the number of stems lost are recognized. In the two wide spacings the pattern was quadratic, and in the three close spacings it was strongly linear (Fig. 4).

DISCUSSION AND CONCLUSION

Wide spacing increased diameter growth of the 25-year-old lodgepole pine. The results are consistent with findings reported for this species by Alexander (1965), Dahms (1967), and Johnstone (1981a, b) and on jack pine (*Pinus banksiana* Lamb.) and red pine (*Pinus resinosa* Ait.) by Bella and De Franceschi (1980). Wide spacing (4.5-m) reduced height growth (significant at $P \leq 0.05$) 15 years following spacing. The reduction of height growth has also been reported earlier by Alexander (1965) and Johnstone (1981a, b); both maintained that a certain degree of crowding enhanced height growth.

Leader and lateral branch growth dictate tree crown development (Brown 1971). In wide spacings, light quality, intensity, photoperiod, and spatial arrangement apparently interact to promote lateral bud development and to suppress terminal leader growth. Wide spacing results in heavy branches, poor tree form, and a lack of strong leader growth. The enlarged lateral crown in wide spacings accelerates diameter growth (Fig. 1), which depends primarily on current photosynthesis (Kozlowski 1962). Under a close spacing the terminal leader maintains complete control over the partially suppressed branches below and induces height growth at the expense of radial growth.

Growth characteristics and spatial requirements for tree development vary with species. Bella and De Franceschi (1980) found that jack pine planted at 3.0-m intervals developed a poor tree form, a lack of strong leader growth, and heavy branches to ground 15 years after planting, while red pine showed no undesirable characteristics.

Density control in forest management is essential to ensure optimum stand development and full utilization of site potential (Hagner 1980). The 4.5-m spacing is too wide for full site occupancy. The resulting relatively high mortality (Fig. 4), poor tree form, reduced height growth (Fig. 2), and low stand production (Fig. 3) strongly suggest that such wide spacing should not be used for lodgepole pine in the Boreal Forest Region.

That height growth at the 1.1-m interval is slower than at intermediate spacings on all sites 15 years after spacing (Fig. 2) may suggest that competition for space, nutrients, and water has begun. Mortality at this spacing is likely to increase as competition becomes acute. Continued periodic remeasurement and analysis will confirm the optimum spacing for this species in western Alberta.

R.C. Yang
September 1986

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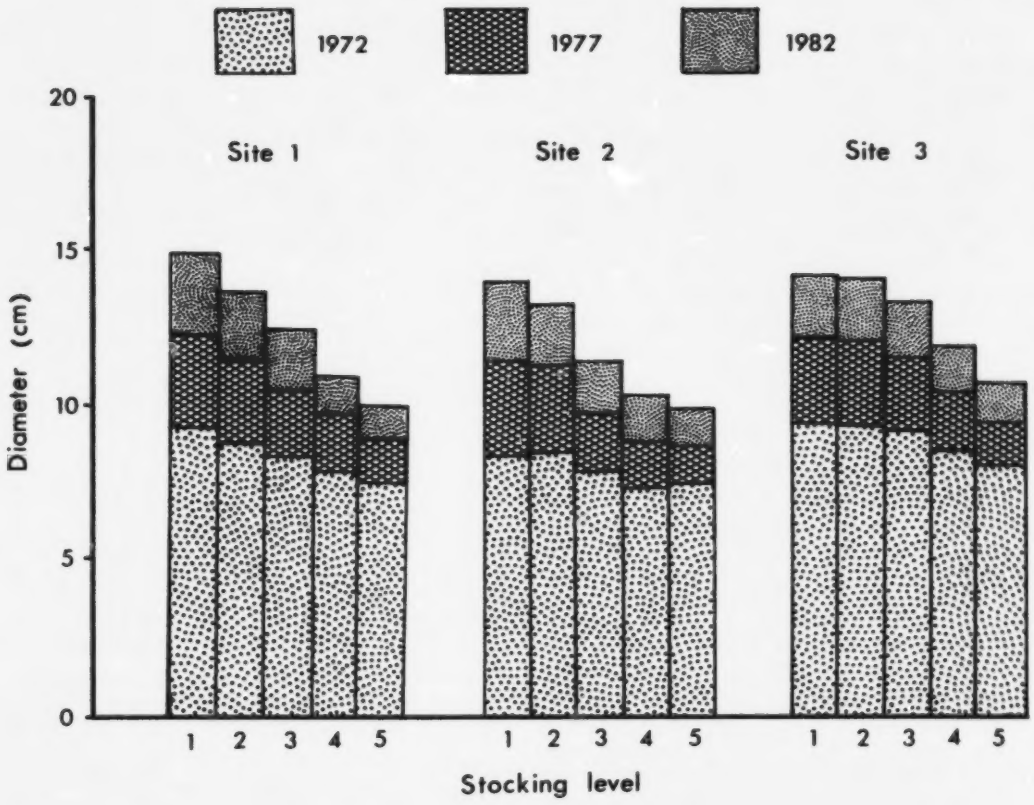

Figure 1. Stand diameter in 1972, 1977, and 1982 at various stocking levels.

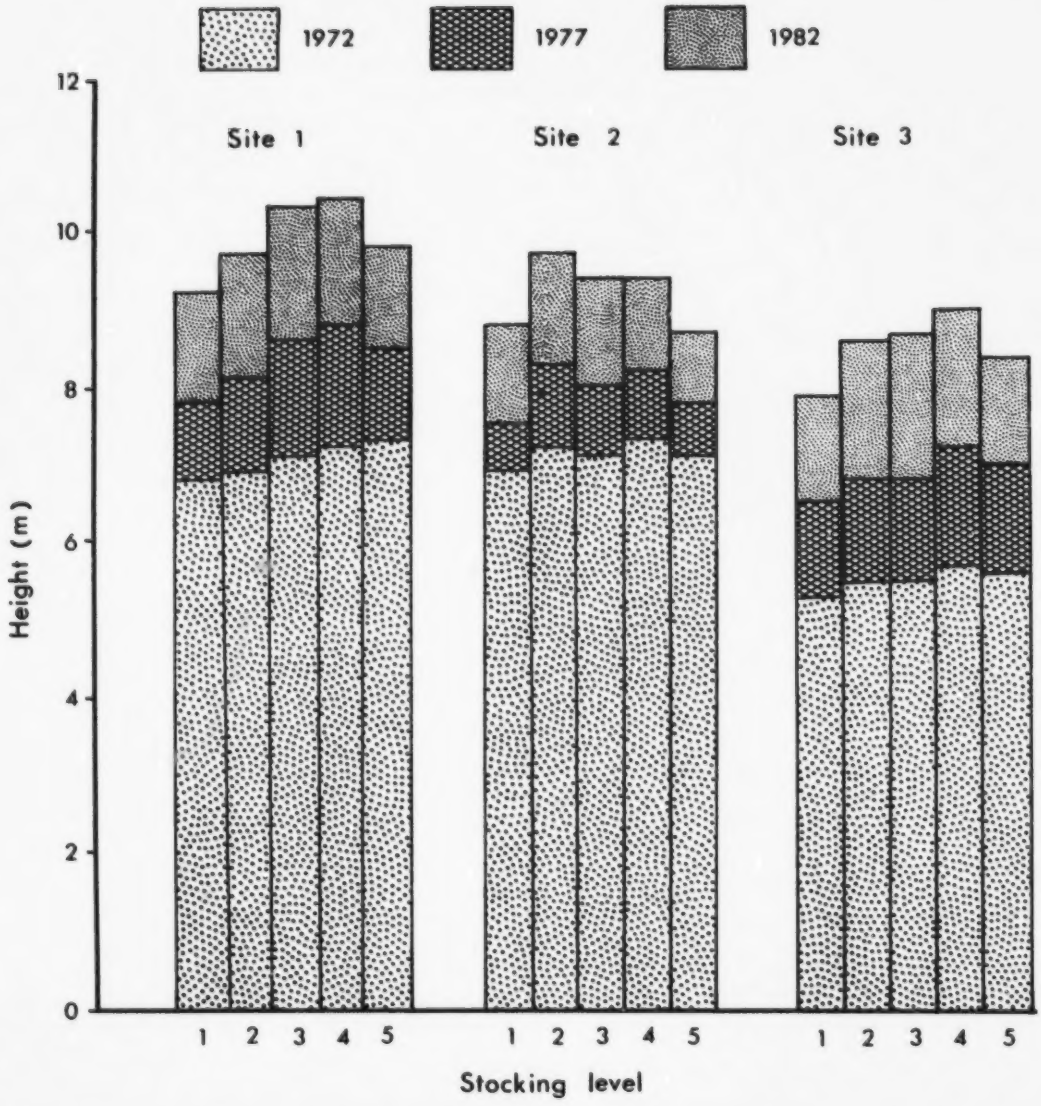

Figure 2. Stand height in 1972, 1977, and 1982 at various stocking levels.

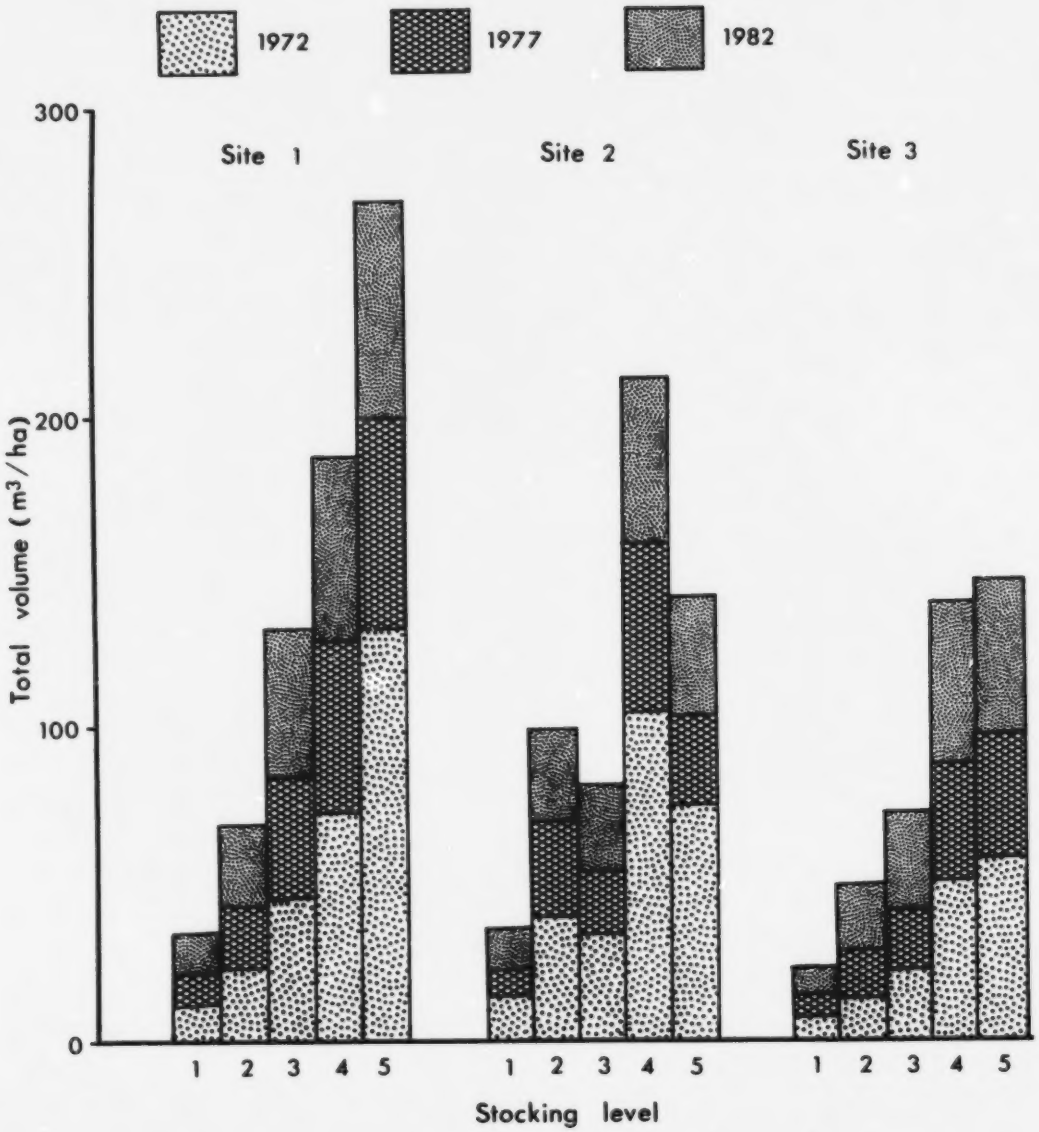

Figure 3. Stand total volume in 1972, 1977, and 1982 at various stocking levels.

Table 2. Average percentage mortality by grid interval and year of measurement

Grid interval (m)	Year of measurement	Percentage mortality	Percentage basal area lost	Percentage stand volume lost
4.5	1972	5.67	3.99	3.86
	1977	9.86	7.70	7.36
	1982	4.78	2.92	2.48
	Average	6.77[bc1]	4.87[c]	4.57[b]
3.2	1972	3.33	2.48	2.39
	1977	3.62	2.03	1.75
	1982	2.68	1.66	1.46
	Average	3.21[a]	2.06[ab]	1.87[a]
2.3	1972	1.51	0.62	0.60
	1977	3.93	2.42	2.19
	1982	3.92	2.66	2.39
	Average	3.12[a]	1.90[a]	1.73[a]
1.6	1972	2.17	1.08	0.90
	1977	4.10	2.45	2.27
	1982	6.14	3.45	2.80
	Average	4.14[ab]	2.33[ab]	1.99[a]
1.1	1972	5.01	1.86	1.60
	1977	8.16	4.65	4.07
	1982	11.29	6.07	5.23
	Average	8.15[c]	4.19[bc]	3.63[ab]
Average	1972	3.54	2.01	1.87
	1977	5.93	3.85	3.53
	1982	5.76	3.35	2.87

[1] Within each group, numbers followed by the same letter are not significantly different at the 5% level.

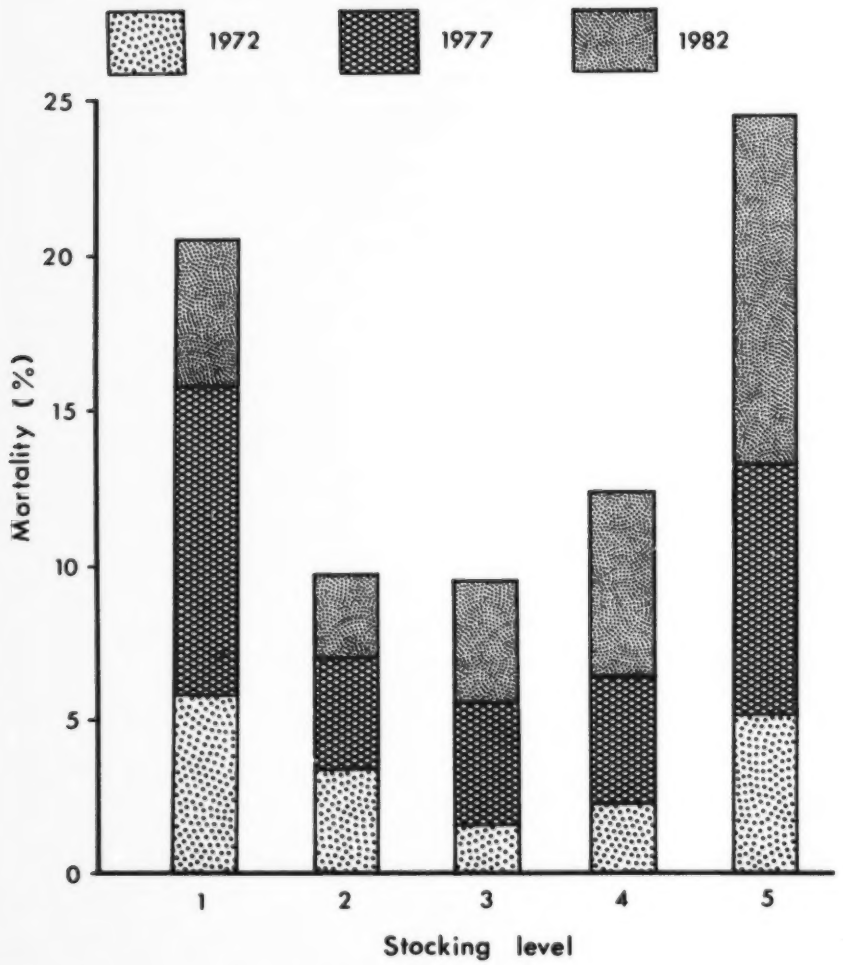

Figure 4. Percentage mortality (no. of stems lost) in 1972, 1977, and 1982 at various stocking levels.

Northern Forestry Centre
5320 -122 Street
Edmonton, Alberta
T6H 3S5 (403) 435-7210

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